

IX. Lunar Spacecraft Development

ENGINEERING MECHANICS DIVISION

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A. 22-inch Air Gun for High-Impact Testing, S. G. Taylor

This article describes the major aspects of the establishment of a high-impact test facility utilizing a 22-in. air gun. Pursuant to the requirements of the High-Impact Survival Program, an existing 22-in. air gun is being converted to accelerate a mass of up to 350 lb to a muzzle velocity of 320 ft/sec. With the proper selection of target material, this provides the desired impact of 10,000 g, 1-msec duration, rectangular wave. The conversion is nearly complete. Two major problems remain to be solved. These will be described in detail.

1. The Air Gun

Fig. 1 shows the air gun located in a subsurface, concrete channel. It shoots a sabot into a target at one end of the channel. Between the two center flanges is a seal plate which separates the accumulator from the barrel. The sabot is held against the seal plate by a tension-release link. Accumulator pressure stresses the link to approximately 80% of its yield strength. The gun is fired by remotely triggering a ram-set. This drives a projectile into the weakest part of the link, causing failure. Only minor modifications were made to the gun itself.

2. Recoil Constraint

A welded steel buttress (Fig. 2) is used to constrain the gun during recoil. This is bolted to the existing deck rails. Its design was based on the maximum allowable floor loading and limits the accumulator pressure to 130 psig. Two steel cables hold the gun carriage firmly against the recoil constraint and a third, at the muzzle, prevents pitching.

3. Target

End grain redwood (6 in. thick) with a nominal density of 25 lb/ft³ and a crush strength of approximately 4000 psi is the impact material used to provide the desired impact profile. Fig. 3 shows the target system, which consists of the matrix of redwood blocks, the peripheral constraints, 8 in. of steel plate backing, and approximately 50 railroad ties for load distribution. The target system is held against the end wall of the channel which is 5 ft thick. A 10,000-g impact crushes the redwood to a depth of about 2 in.

4. Sabot

The existing sabot is both too expensive and too heavy for practical testing. Some improvements have resulted in

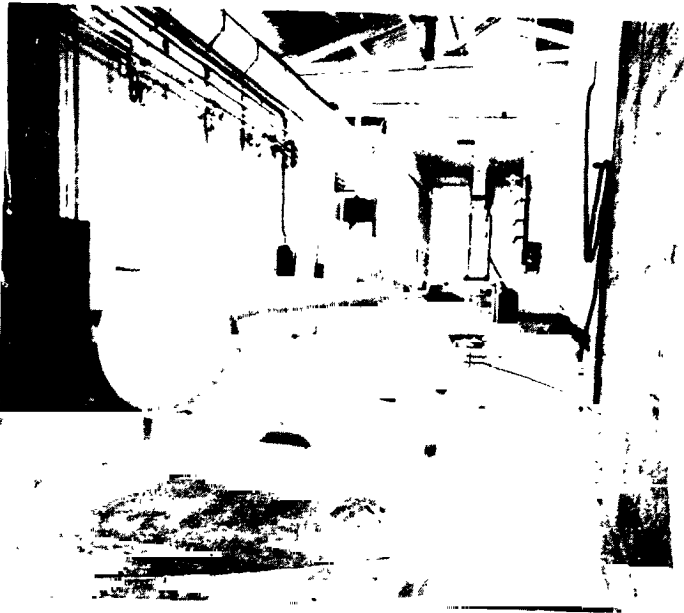


Fig. 1. Air gun in channel

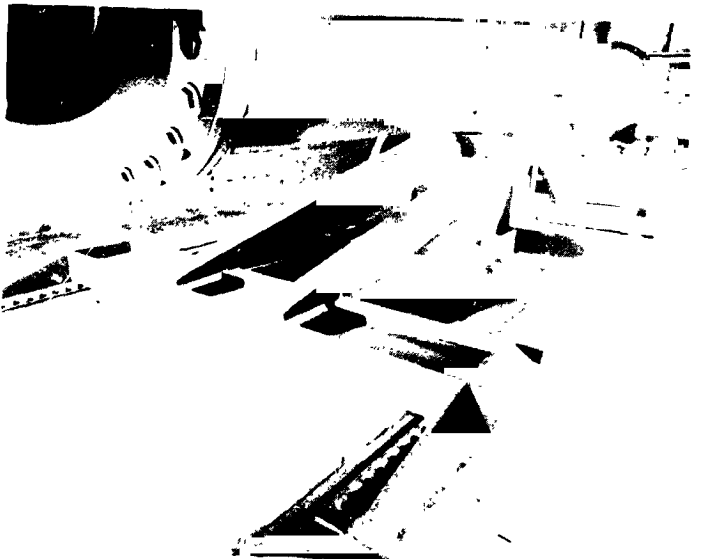


Fig. 2. Welded steel buttress

cutting the mortality rate from one per shot to one per two or three shots; however, a failure usually requires scrapping the entire sabot. Fig. 4 shows the existing sabot with the front (impact) plate removed, and Fig. 5 shows a model of what is expected to be an improved design. An attempt is being made to design a sabot that will be lighter in weight and strong enough to allow re-use of at least the more expensive parts. The parts will be bolted together so that damaged parts can be replaced. A scaled model of this design (Fig. 5) is undergoing impact tests on a 2.75-in. air-gun test facility for design optimization.



Fig. 3. Target system



Fig. 4. Sabot with impact plate removed



Fig. 5. Model of improved sabot design

Its full-scale weight would be approximately 160 lb. This compares favorably with the present sabot weight of 260 lb.

5. Instrumentation

Muzzle velocity is measured with magnetic pick-ups and shear pin pick-ups mounted in the gun barrel. These signals are fed into electronic counters which display the time the sabot took to travel between pick-ups. Impact acceleration is measured with a piezoelectric accelerometer mounted on the inside face of the impact plate of the sabot. Its signal is fed into an oscilloscope equipped with a camera for photographing the impact wave form. All data is simultaneously recorded on magnetic tape. The most critical problem is getting the acceleration signal from the sabot to the readout instrumentation. Three different cable pay-out systems have been tried without success. A Micro-dot coaxial cable supported by fiberglass tape and an AWG #20, two-conductor, shielded, jacketed

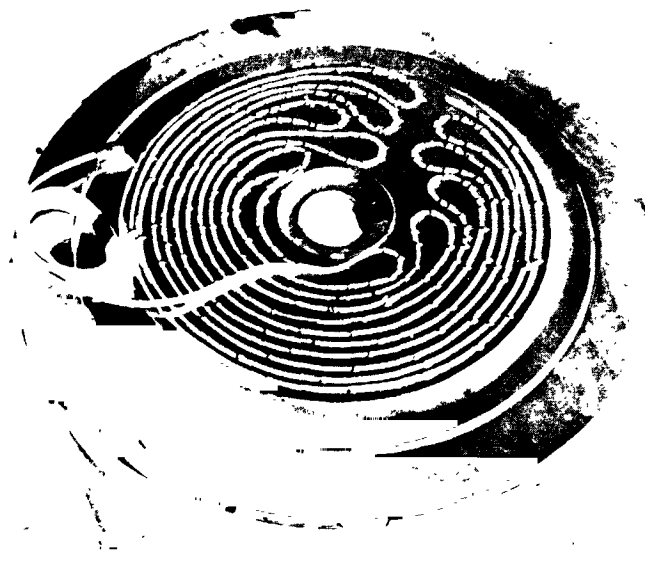


Fig. 6. Cable cast in silicone rubber

cable both failed in tension. An Amphenol coaxial cable failed in shear due to twisting, but satisfactorily resisted tensile loading and abrasion. Fig. 6 shows this same cable cast in silicone rubber in a non-twist configuration. This system will be used on the next test.

6. Status

Three test shots have been made to date. Several more will have to be made before the remaining problems are solved and an adequate system calibration is obtained. There remain two major problems: sabot design and the pay-out cable system. Each of these shows promise of solution in the immediate future. The tests thereafter will be for the purpose of obtaining calibrations of acceleration versus pressure and velocity versus pressure. Measurements of the crush strength of the redwood and the depth of penetration of the sabot have given a rough indication that the calculated accumulator pressure based on an adiabatic expansion process has been close. These indications, however, are not adequate for actual test purposes. Several measured test points will have to be obtained before the facility is operational.